# The Future Interaction of Science and Innovation Policy for Climate Change and National Security

Elizabeth L. Malone, Andrew J. Cowell, Roderick M. Riensche
Pacific Northwest National Laboratory
PO Box 999
Richland, WA 99352 USA

*Abstract* - **Recent efforts to characterize the interactions among climate change and national security issues raise challenges of relating disparate bodies of scientific (both physical and social) knowledge as well as determining the role of innovation in meeting these challenges. Technological innovation has been called for to combat climate change, increase food production, and discover new ways of generating energy, and proposals for increased investments in R&D and technology deployment are to be met with everywhere. However, such policy decisions in one domain have impacts in other domains—often unexpected, often negative, but often capable of being addressed in planning stages.**

**This technological tool allows its users to embody the knowledge of different domains, to keep that knowledge up to date, and to define relationships, via both a model and an analytic game, such that policy makers can foresee problems and plan to forestall or mitigate them. Capturing and dynamically updating knowledge is the accomplishment of the Knowledge Encapsulation Framework. A systems dynamic model, created in STELLA®, simulates the relationships among different domains, so that relevant knowledge is applied to a seemingly independent issue. An analytic game provides a method to use that knowledge as it might be used in real-world settings.**

## I. Background

Globalization collapses the boundaries between political, economic, and socio-cultural domains. No longer is it possible to specialize in one of these domains without accounting for the others. Researchers who wish to contribute to human well-being and address real-world issues of science and innovation must increasingly cross-disciplinary boundaries and tread in interdisciplinary territory. And the complexity of global systems (whether truly increasing or simply increasingly recognized) demands new computerized tools to represent important factors of these real-world issues. The real-world issues themselves include active debates about the development – and the desirability – of new technologies.

Recent efforts to characterize the interactions among climate change and national security issues raise challenges of relating disparate bodies of scientific (both physical and social) knowledge as well as determining the role of innovation in meeting these challenges. As discussion about climate change (especially in the United States) have shifted from "Is it real?" to "What to do?," debates have focused on technological approaches to generating emissions-free energy and preserving/extending natural carbon sinks. But pilot- or commercial-scale implementations of single technologies often reveal issues in other domains. For instance, expansion of wind energy is championed by environmental groups as non-emitting and environmentally benign, but concerns about bird kills, aesthetic issues, and intermittency may limit such expansion. Carbon dioxide capture and storage (CCS), in which carbon dioxide is removed from emissions streams and sequestered in deep geologic or ocean sites, promises continued use of cheap fossil fuels, but these technologies also increase the cost of energy and are raising safety concerns.

Technological innovation has been called for to combat climate change, increase food production, and discover new ways of generating energy, and proposals for increased investments in R&D and technology deployment are to be met with everywhere. However, such policy decisions in one domain have impacts in other domains—often unexpected, often negative, but often capable of being addressed in planning stages.

Under the Technosocial Predictive Analytics Initiative at Pacific Northwest National Laboratory, linked research teams are providing a new and significant capability for government analysts and policymakers to make better policy decisions about such innovation. The teams have developed a case study focusing on India (with plans to include Pakistan and Bangladesh) in the areas of food, energy, and national security. The case study includes three aspects, visualized in Fig. 1:

- Knowledge Encapsulation Framework (KEF), a semantic wiki-based collaborative environment that holds traditional documents and continually updated social media
- STELLA® model that draws from three existing models in the areas of food and energy security, and social resilience to climate change
- An analytic game based on issues that the model addresses. Information seekers, users of the model and players of the game will see how different domains relate to each other and where innovation is needed.

The next sections of this paper discuss each element, then provide a use case involving decisions about expanding the production of biofuels while safeguarding food security.

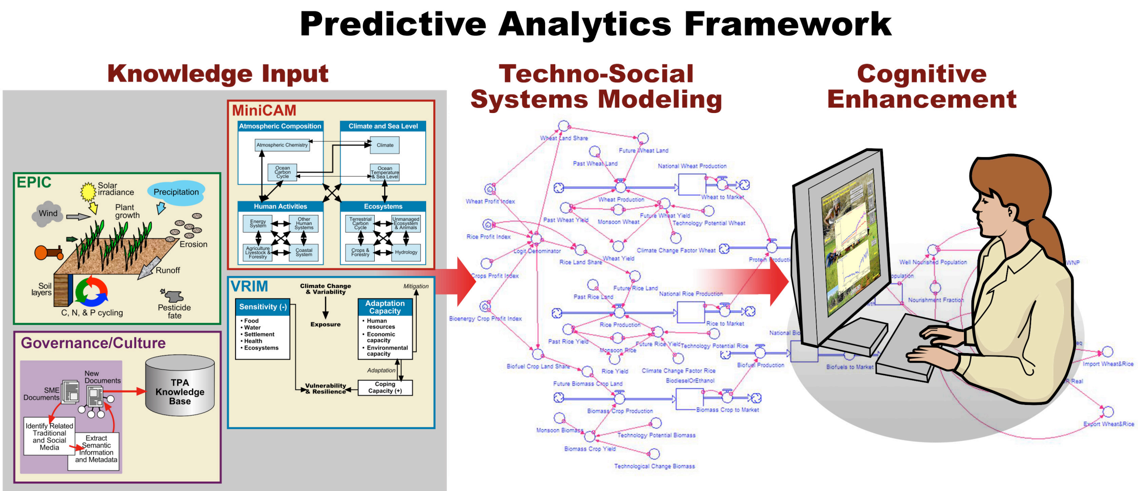


Fig. 1. Elements of a predictive analytic framework.

## II. The Knowledge Encapsulation Framework – A Dynamic, Collaborative Environment for Information Discovery

A primary challenge in interdisciplinary research and model-building is to understand basic concepts and cutting-edge work in many fields. Mastering the wealth of knowledge available is daunting. Researchers across all domains in academia, industry, and government have the onerous task of keeping up with literature in their fields of study and related fields. The use of the Internet has made long distance collaborations possible and has increased productivity of researchers in general. In addition, the Internet makes it easier for academic journals, conferences, workshops, and individual researchers to put the fruits of their labor in front of a larger audience. The Internet has also made it easier than ever to perform searches and find relevant information.

However, the use of the Internet as a research tool has its limitations because of the sheer quantities of data available; a search that returns several million hits is hard to review, and more pointed searches may miss important information. Moreover, the quality of the data may be often questionable (not to mention the multitude of file formats and standards). In the sea of Adobe PDF and Microsoft Word files that take up space on their (electronic) desktop, researchers are finding it more difficult to identify relevance and significance of individual articles in the mass of similarly titled material. Once material is found, the benefits of electronic media end there: researchers are still printing out relevant documents and making notes in margins. In addition, researchers will send links for electronic documents to their collaborators and each will individually print and make margin annotations.

The Knowledge Encapsulation Framework (KEF) is a suite of tools enabling relevant, domain-specific knowledge to be filtered with specialized tools, easily vetted, and incorporated into modeling and simulation projects, as well as into other domains that require effective collaborative workspaces for knowledge-based task. Building on previous work in understanding computer-supported cooperative work [1], this framework can be used to capture evidence (e.g., trusted material such as journal articles and government reports), discover new evidence (covering both trusted and social media), enable discussions surrounding domain-specific topics and provide automatically generated semantic annotations for improved corpus investigation. The current KEF implementation is presented within a semantic wiki environment, providing a simple but powerful collaborative space for team members to review, annotate, discuss and align evidence with their modeling frameworks. The novelty in this approach lies in the combination of automatically tagged and user-vetted resources, which increases user trust in the environment, leading to ease of adoption for the collaborative environment. In addition, the framework allows for the analysis of both social and traditional media, integrated together with tools to help the user understand the potential credibility differential. Finally, the environment includes a powerful discovery mechanism that can take user-suggested seed documents, extract associated semantic relationships and metadata, and use these to submit search queries to literature portals (e.g., Google Scholar) and automatically parse and insert the results back into the environment.

The fundamental concept for KEF has been investigated across a number of disciplines for a number of years. Experts systems [2],[3] research have tried to capture the tacit knowledge residing within a specific domain (usually through the elicitation of that knowledge from subject matter experts) so that this information can be shared and transferred to other members. Our work does not attempt to codify or understand the knowledge that an SME brings to a problem. The KEF environment simply provides a collaborative environment where such individuals can collectively discuss and discover new facts within a dynamic stream of incoming information. In addition, a common interface to an expert system is to consider it to *be* an expert that can answer questions either through a traditional text-based interface or a more anthropomorphic representation that may appear to have human form and that can listen and talk to the user [4]. KEF, on the other hand, is simply an environment that allows for the discussion and evolution of new knowledge and ideas. There is also often a significant amount of effort placed in engineering the knowledge structure in expert systems so that reasoning can occur to handle unforeseen situations. While KEF does attempt to annotate semantic relationships identified within the data sources, these are not hard-coded ontologies – rather, we build up a categorization scheme based on the content identified. Finally, typical expert systems focus on a very narrowly defined domain, such as Mycin and CADUCEUS (both medical diagnosis systems), NeteXPERT (network operations automation system), KnowledgeBench (new product development applications) and Dipmeter Advisor (oil exploration system). The concepts set out for KEF can be generalized for any domain.

Collaborative problem solving environments (CPSE) are perhaps a better analogy for the concept KEF is attempting to convey. The Pacific Northwest National Laboratory has a long history of building CPSE's for Department of Energy (DOE) scientists [5], such as the DOE2000 Electronic Notebook Project [6]. Watson reviewed a number of organizations pursuing CPSE's including other DOE sites (e.g., Common Component Architecture, Collaboratory Interoperability Framework, Corridor One Project) as well as the Department of Defense (e.g., Gateway), NASA (e.g., Intelligent Synthesis Environment (ISE), Collaborative Engineering Environment (CEE) and Science Desk) and numerous university efforts (Rutgers University's Distributed System for Collaborative Information Processing and Learning, University of Michigan's Space Physics and Aeronomy Research Collaboratory and Stanford's Interactive Workspaces) [7]. Shaffer, in his position statement on CPSE's defined them as a "system that provides an integrated set of high level facilities to support groups engaged in solving problems from a proscribed domain" [8]. These facilities are most often directly related to the domain, e.g., facilities to enable 3D molecular visualization for biologists. KEF includes a number of components but the focus has always been on the general case – i.e., development of capabilities that apply across a number of domains. Within CPSE's, there is also significant amount of effort placed in encouraging synchronous interaction, a facility provided by KEF through an integrated textual chat component but secondary to the asynchronous wiki implementation. Perhaps the most striking difference between traditional CPSE's and our implementation of KEF is the scale of effort. Many of the CPSEs mentioned above were created over a number of years at the cost of millions of dollars, and have an excessive learning curve and setup time. KEF, while leveraging the experiences of these previous systems, is built using open-source software (e.g., the same wiki framework used in Wikipedia[1]) and is configurable within a few hours.

Perhaps the most similar technology currently available to KEF are the 'web 2.0' information stores available on the Internet. Examples include encyclopedic resources such as Wikipedia and Knol[2] that rely on 'wisdom of the crowds' to build and maintain a knowledge base of information. Such resources rarely utilize automated processes to extract semantic relations and add these as additional metadata that can aid in the discovery process[3]. Like KEF, some of these systems use tags to provide an informal tagging mechanism but the domain scale are typically very wide (in the case of Wikipedia, the goal is to provide an encyclopedia's worth of knowledge). Project Halo is specific instance of an information store that aims to develop an application capable of answering novel questions and solving advanced problems in a broad range of scientific disciplines (e.g., biology, physics, and chemistry). The mechanism for inserting knowledge into the data store (i.e., using graduate students with domain knowledge) requires significant effort. The KEF approach is to share the load between automated information extraction tools and domain experts. While we acknowledge the limitations of automated information extraction technologies, we believe an approach that leverages automated means while encouraging users to make corrections and provide their own annotations may provide significantly rich metadata. Fig. 2 shows the process model for KEF while Figs. 3-6 show screenshots of the KEF environment in use.

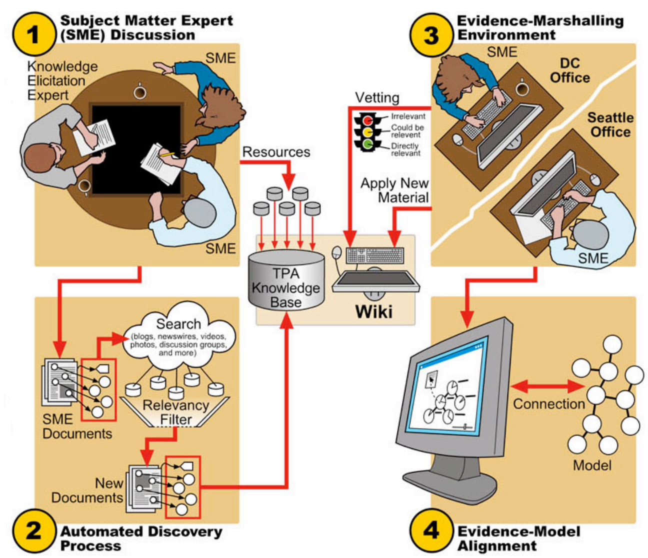


Fig. 2. KEF process model.

## III. Climate Change and National Security: Modeling the Connections

Researchers can use computerized tools to integrate disparate domains of knowledge and define their interconnections. This project integrates and models connections and interactions among several general domains: natural resources (agriculture, water resources, and unmanaged ecosystems), energy and economics, national security (especially with regard to food and energy security), and governance and culture, all under conditions of climate change.

---

[1] http://www.wikipedia.org

[2] http://knol.google.com

[3] Although a new effort entitled DBpedia (http://dbpedia.org) is a community effort to extract structured information from Wikipedia.

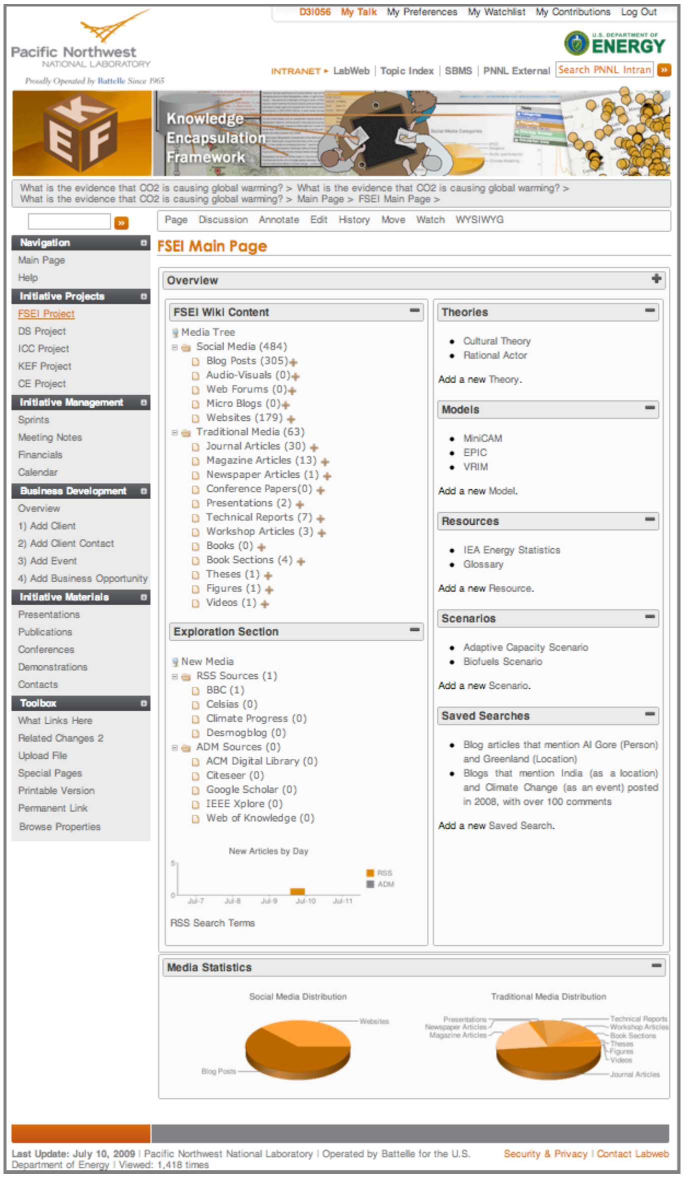


Fig. 3. Main page of KEF.

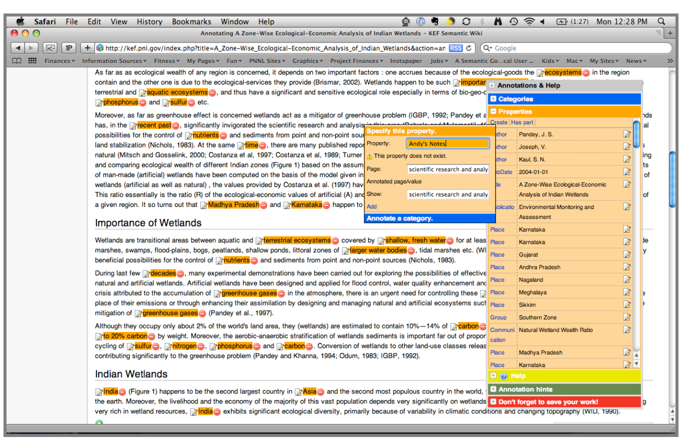


Fig. 4. KEF annotation interface.

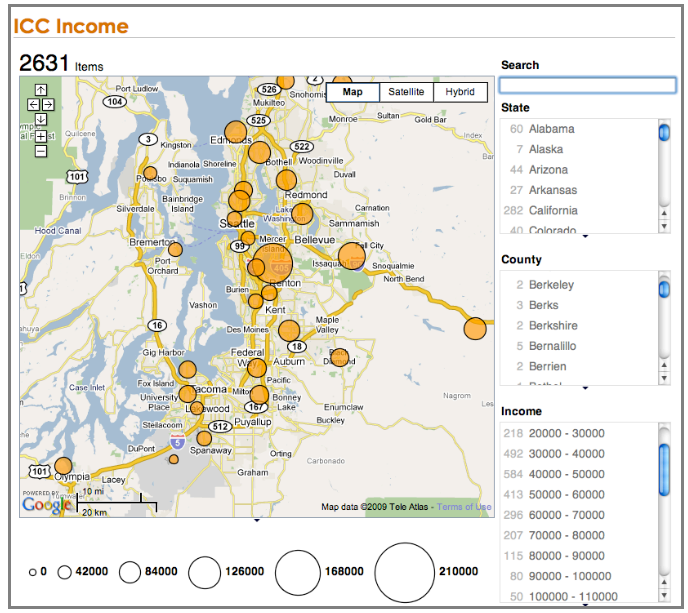


Fig. 5. Displaying census information.

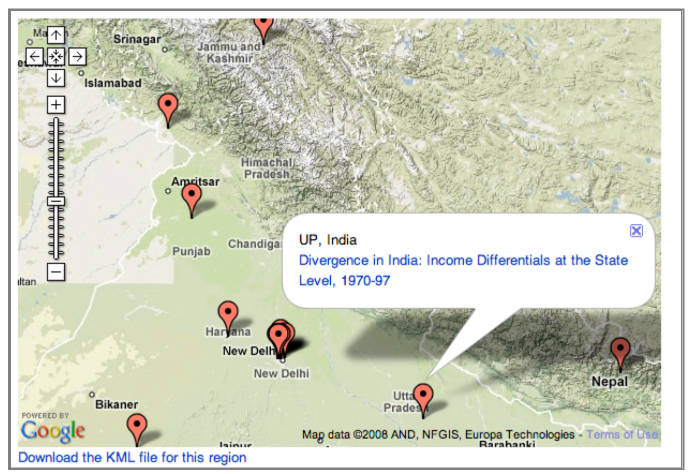


Fig. 6. Displaying geographical content.

The project focuses on India, Pakistan, and Bangladesh, with the prototype model featuring India. Joined by history and geography, divided by ethnicity, religion, and governance, at least two of these three countries are in some senses failed states, but tremendously important geopolitically; and they are among the most vulnerable areas in the world to climate change. So their current situation and prospects for the future demand helpful tools for analysts who wish to make robust policy about the role of science and innovation.

To integrate domains of knowledge about these three countries, the research team is starting with three existing models designed to examine (1) greenhouse gas emissions, climate change, and mitigation scenarios (MiniCAM); (2) agriculture and ecosystems (EPIC); and (3) social and environmental resilience to climate change (VRIM).

- MiniCAM, an integrated assessment model of moderate complexity in its component parts, focuses on the energy and agriculture sectors. The MiniCAM incorporates a reduced-form climate model to calculate the global-mean temperature and sea-level consequences of emissions scenarios, which are then passed to the agriculture and land-use module, which simulates food and fiber supplies and demands along with associated emissions and land-use changes. Technologies that reduce emissions are also modeled [9], [10].
- EPIC [Environmental Policy Integrated Model], a watershed-scale biophysical model capable of simulating a wide array of agricultural management as well as non-agricultural land uses such as tree plantations, grasslands, and biomass crops. Within the Joint Global Change Research Institute (JGCRI), EPIC has been used to analyze agricultural productivity in response to interannual climate variability in the conterminous United States, and climate change in the conterminous United States and the Huang-Hai Plain of China [11], [12].
- VRIM [Vulnerability-Resilience Indicators Model], which aggregates a number of social and environmental proxy values into sectors, then into sensitivity and adaptive capacity values, and finally into a resilience index. Developed at JGCRI, VRIM provides comparative analysis of an area's social-ecological resilience with regard to various stressors; the set of indicators can be modified or expanded to address particular concerns [13], [14], [15], [16], [17].

To the existing model building blocks the scientific team is adding knowledge about governance and social capital/civil society. To date, many of the connections between climate change impacts and human security issues (including conflict) have been made via narratives. For example, "water wars" stories have connected projected water scarcity with armed conflict, and "environmental refugee" stories have connected climate change conditions with privations that drive people from their homes and perhaps across international borders, resulting in massive social problems. Integrating governance and social capital/civil society with other forms of knowledge permits evaluation of potential scenarios and helps account for other-than-technical and other-than-rational aspects of decision-making. For instance, there are many rational reasons why a country such as India should engage in emissions mitigation—the benefits of clean, energy-efficient development, for one, or the opportunity to engage in profitable bilateral trading of emissions rights. But India maintains its position that the developed world must act first; as a matter of international equity. Its fierce desire to be independent of the West, and other historically established leanings, may trump rationality. Or another rational national goal—maintaining the pace of economic development—may take precedence over climate stabilization efforts.

The research team has created a new modeling space in which data, variables, and results from MiniCAM, EPIC, and VRIM can be combined in an integrated, systems theoretical way. The prototype focuses on the issue of expansion of biofuels in India, thus bringing together the domains of climate change, energy security, and food security. We are using STELLA®,[4], a well-established social science tool. STELLA offers the ability to develop a working model quickly, integrate disparate kinds of knowledge, and encompass whole systems that include physical, biological, and social aspects. Users of the model can increase or decrease the values of certain variables (in this case, prices) to examine the results of changing policies on the outcome.

The prototype focuses on the issue of biofuels—an integrated issue of scientific innovation policy that affects energy and climate change, with implications for national security. An analyst or policymaker seeks to understand, first, how everything connects to everything else and, second, how various interventions could affect the evolution of a complex system. What happens if, to achieve some energy independence, a country wishes to provide incentives to grow biofuel crops? The energy system and its infrastructure will be changed by an infusion of biofuels. On the agricultural side, land-use changes, both in terms of cropland (which may change in extent and intensity) and agricultural output (which changes to include biofuel crops and potentially decrease quantities of food crops). Prices of all these commodities will also change (rising food prices, perhaps stable biofuel prices with government subsidies, lower prices of energy fuels like oil that are displaced).

The user can set prices for wheat, rice, and biofuels crops in India, then run the model to see how much is produced of each crop, then converts crop production into protein that can be consumed. The model then partitions that protein into a well-fed elite, who will always get enough, and a poorer segment of the population, who may experience higher food prices, unavailability, or both if biofuel crops prove very attractive to farmers. A panic button changes from green to yellow to red to indicate deficits in the undernourished part of the population. The user can stop the model and adjust prices to balance levels of production across the three crops and achieve domestic food security as well as biofuels production.

In the prototype, an analyst can explore what level of biofuels can be produced without negative consequences, such as food shortages and active protests—and, thus, what the dimensions of the policy to encourage biofuels production should be. Land will get pulled into biofuels production, but only up to some limit (an absolute limit defined by the physical world, or a lower limit based on a need for food security). Similarly, food prices would likely only rise to some limit. Thus, the analyst would be able to understand the potential limits of biofuels production under different sets of circumstances.

## IV. Analytic Gaming – A Framework for Exploration of Modeled Environments

As our ability to generate and execute complex models describing natural phenomena and social dynamics continues

[4] http://www.iseesystems.com/softwares/Education/StellaSoftware.aspx

to increase, so too does the volume of data available to researchers and decision makers as they try to leverage these models to make more informed decisions. While some predictive models may be used to generate definite answers to specific questions, others describe a range of predicted behaviors of a system (or persons). When these various types of models are combined, the resulting aggregate models produce a complex "information space" that describes a wide range of possible futures, using the knowledge of experts that has been encapsulated in the models.

This information space is often more complex than a simple response surface, which shows how a dependent variable varies in response to one or more independent variables. Not only is the dimensionality often much higher (in even a simple predictive model, there may be a half-dozen or more input parameters) but the response itself may be multi-valued, uncertain, and be associated a significant amount of tacit information about underlying assumptions, model limitations, and history.

How then might we explore this information space, and to what end? There are multiple reasons to do so (and they are ultimately similar to reasons that we model complex systems to begin with: to better understand how the systems work and to identify the ways in which we may influence them to bring about a desirable outcome). One way to explore such an information space is through the use of analytic gaming. At its core, gaming is a storytelling exercise, with the rules of the game defining the rough shape of a story, and a particular instance of the game played out to describe one discrete story. If we consider the desired outcomes of a better understanding of a system, and of the ways in which we may influence it, the use of gaming provides a way to augment the outputs of models with human insight, allowing human players to fill in any gaps in the knowledge modeled, or to compare human player actions with predicted behaviors. By playing such a game, we are fleshing out a narrative (or, as the game is played repeatedly, a set of narratives) describing a potential future scenario.

As part of our "Analytic Gaming" project, we have defined a framework that describes an abstract set of elements that make up a model-driven game [18]. These include well-known elements of common games (e.g. a set of players, the roles of each player, a set of game rules that define how the players may act), and some specific ideas that we introduce to facilitate coupling of games with predictive models. For instance, a "game parameter" is introduced as a unit of data that describes the state of the game and defines the interface between the game and the models' information space; "handles" are the interfaces by which players may influence the state of the game, and "widgets" provide the user interface by which players manipulate handles. Defining game rules based on these elements allows us to weave into the rules a set of points at which we consult the underlying model for a decision of "what happens next."

The importance of defining these in the abstract is that by so doing we enable the one-time construction of a framework architecture, which may then be utilized to rapidly develop specific games based on particular sets of models, allowing customized exploration based on the question at hand. For example, given a game parameter that is generally controlled by a predictive model, we could easily "unhook" it and attach it instead to a handle to allow a human player to assume control of a piece of the modeled environment, providing a way for "what if" analysis and to compare the choices of an expert player with the "choices" made by a predictive model.

An important function of such a framework is to capture data about each instance of game play. Understanding what happened during a game session is key to understanding why a game instance unfolded in a particular way, and is important for evaluating the game's analytic effectiveness [19]. We ultimately seek to gain enough information from a game session to provide a narrative description of a potential scenario. To that end, our framework captures information about game state over time (again, the collection of game elements), as well as player actions (via handles). This data provides the capability to look back and replay a particular game for an after-action report, with the luxury of time to consider why, when, and how a player (or model, for that matter) may have changed a game parameter.

Our currently developed system implements the abstract elements of this framework, and allows creation of computerized implementations of a game described in these framework elements. It has been designed and built for extreme extensibility, with a separation between "parameters" "handles" and "widgets" that allows alternative models, rules, and user interfaces to be defined without having to re-code underlying mechanics.

## V. Use Case – Biofuels Production in India

An analyst (e.g., decision-maker, policymaker, intelligence analyst) seeks to understand, first, how everything connects to everything else and, second, how various interventions could affect the evolution of a complex system. What happens if, to achieve some energy independence, a country wishes to provide incentives to grow biofuel crops? The energy system and its infrastructure will be changed by an infusion of biofuels (ethanol may initially be added to gasoline and require no modification other than in refining, but eventually modifications of vehicles will be required). On the agricultural side, land-use changes, both in terms of cropland (which may change in extent and intensity) and agricultural output (which changes to include biofuel crops and potentially decrease quantities of food crops). Prices of all these commodities will also change (rising food prices, perhaps stable biofuel prices with government subsidies, lower prices of energy fuels like oil that are displaced).

In the prototype, an analyst can explore what level of biofuels can be produced without negative consequences, such as food shortages and active protests. Land will get pulled into biofuels production, but only up to some limit (an absolute limit defined by the physical world, or a lower limit based on a need for food security). Similarly, food prices would likely only rise to some limit. Thus, the analyst would be able to understand the potential limits of biofuels production under different sets of circumstances.

The model interface demonstrates these interconnections to the user through a "panic button" that appears green when food production is still meeting the dietary needs of both the "well-nourished" and "under-nourished" portions of the population. When food production falls short of meeting these needs (the lack showing up in the under-nourished population), the panic button changes to yellow and, as the food shortages grow, to red. The user can either adjust profit margins on food and biofuels crops to achieve a balance between the two or use a feedback mechanism in the model to accomplish the same goal.

## VI. Conclusion

Designing and implementing effective policies in a globalized world must account for consequences in domains other than that of the specific policy. This technological tool allows its users to embody the knowledge of different domains, to keep that knowledge up to date, and to define relationships, via both a model and an analytic game, such that policy makers can foresee problems and plan to forestall or mitigate them.

## References


[1] A.J. Cowell, M.L. Gregory, J. Bruce, J.N. Haack, D.V. Love, and S.J. Rose, "Understanding the dynamics of collaborative multi-party discourse." *Journal of Information Visualization,* vol. 5(4), pp. 250-259, 2006.

[2] J.P. Ignizio, "Introduction to Expert Systems: The Development and Implementation of Rule-Based Expert Systems," McGraw-Hill. 1991.

[3] P. Jackson, "Introduction to Expert Systems (3rd Edition)," Addison Wesley, 1998.

[4] A.J. Cowell, and K. Stanney, "Manipulation of Non Verbal Interaction Style and Demographic Embodiment to Increase Anthropomorphic Computer Character Credibility." *International Journal of Human-Computer Studies,* vol. 62(2), pp. 281-306, 2004.

[5] PNNL, "Collaborative Problem Solving Environments," 2002. [Online]. Available: http://www.pnl.gov/cpse/whatwedo.stm. [Accessed: September 22, 2008].

[6] J.D. Myers, et al., "Electronic Laboratory Notebooks for Collaborative Research." In Proceedings of WETICE '96. Stanford University, June 19-21, 1996. *IEEE Computer Society*, pp. 47-51, 1996.

[7] V.R. Watson, "Supporting Scientific Analysis within Collaborative Problem Solving Environments," In HICSS-34 Minitrack on Collaborative Problem Solving Environments, Maui, Hawaii, January 3-6, 2001.

[8] C.A. Shaffer, "Collaborative Problem Solving Environments," 2006. [Online]. Available: http://people.cs.vt.edu/~shaffer/Papers/DICPMShaffer.html. [Accessed: October 2, 2008].

[9] Brief Description of the ObjECTS MiniCAM Model. 2008 [Online]. Available: http://www.globalchange.umd.edu/models/minicam/.

[10] S.H. Kim, J.A. Edmonds, J. Lurz, S.J. Smith and M.A. Wise, "The Object-oriented Energy Climate Technology Systems ,ObjECTS) framework and hybrid modeling of transportation in the MiniCAM long-term, global integrated assessment model." *The Energy Journal*, 2006.

[11] A.M. Thomson, R.C. Izaurralde, N.J. Rosenberg and X. He, "Climate change impacts on agriculture and soil carbon sequestration potential in the Huang-Hai Plain of China." *Agriculture, Ecosystems and Environment,* vol. 114, pp. 2-4, 2006.

[12] A.M. Thomson, N.J. Rosenberg, R.C. Izaurralde and R.A. Brown, "Climate change impacts for the conterminous USA: an integrated assessment, part 2, Models and Validation." *Climatic Change,* vol. 69(1), pp. 27-42, 2005.

[13] A.L. Brenkert, and E.L. Malone, "Modeling vulnerability and resilience to climate change: a case study of India and Indian states." *Climatic Change,* vol. 72, pp. 57-102, 2005.

[14] A.L. Brenkert, M. Ibarrarán, E.L. Malone, and L. Herrara, "Vulnerabilidad y resilencia ante el cambio climático: un análisis exploratorio para México." Presented to Políticas Publicas para Crecimiento y Desarrollo, IBERGOP, August 28, 2006.

[15] G. Yohe, et al., "A synthetic assessment of the global distribution of vulnerability to climate change from the IPCC perspective that reflects exposure and adaptive capacity." Center for International Earth Science Information Network (CIESIN), Columbia University, New York, NY. 2006a. http://ciesin.columbia.edu/data/climate/

[16] G. Yohe, E.L. Malone, A.L. Brenkert, M. Schlesigner, H. Meij, and D. Lee. "Geographic Distributions of Vulnerability to Climate Change." *Integrated Assessment Journal,* vol. 6(3), 2006b.

[17] E.L. Malone and A.L. Brenkert. "Uncertainty in resilience to climate change in India and Indian states." *Climatic Change,* vol. 91, pp. 451-476, 2008.

[18] R.M. Riensche, et al., "Serious Gaming for Predictive Analytics." In AAAI Spring Symposium on Technosocial Predictive Analytics. Association for the Advancement of Artificial Intelligence (AAAI), San Jose, CA. 2009.

[19] R.M. Riensche, L.M. Martucci, J. Scholtz, and M.A. Whiting. "Application and Evaluation of Analytic Gaming." In 2009 International Conference on Social Computing. IEEE SocialCom09, Vancouver, BC., in press.